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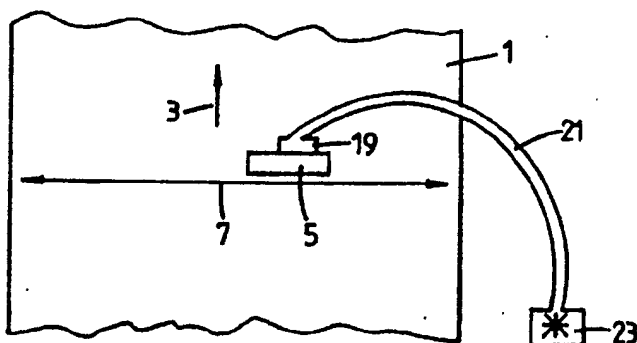
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(54) Title: INK JET PRINTER WITH APPARATUS FOR CURING INK AND METHOD

(57) Abstract

A process and apparatus for forming an image on a moving substrate (1) involves ink jet printing a radiation-curable ink onto the substrate with a print head (4). The image is cured by exposure to a radiation source (19). The time between printing and curing is substantially the same for all portions of the substrate (1).



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## INK JET PRINTER WITH APPARATUS FOR CURING INK AND METHOD

This invention is concerned with improvements in and relating to printing apparatus and processes, more especially ink jet printing processes and, particularly, such processes employing radiation-curable inks such as UV-curable inks.

Ink jet printing processes are well known and well established (see, for example, "Output Hardcopy Devices", Durbeck R.C. and Sherr S., Eds. Academic Press Inc., 1908, at pages 311-370). The use of radiation-curable, especially UV-curable, inks in such a process would appear highly desirable since, after appropriate curing, radiation curable inks afford a tough, durable image upon the substrate to which they are applied. This makes the process especially applicable to printing on plastics packaging where high durability is required. Therefore, it can be applied not only to conventional cellulosic substrates such as paper and board, but also to synthetic polymeric substrates.

We have found that problems can be encountered in printing a radiation-curable ink upon a substrate by an ink jet printing process and subsequently curing the substrate, bearing the uncured printed image, by exposing it to radiation in a conventional manner. Thus in accordance with usual procedures, substrates bearing uncured radiation-curable images are cured by passing them under one or more radiation sources (e.g. mercury vapour lamps in the case of UV-radiation) at a relatively high linear speed. Since ink jet printing is relatively slow, as compared with some other printing methods, the first printed portion of a substrate may well bear an uncured image for a markedly longer period of time than the last printed portion of that substrate, before curing of the printed image. We have found that this can give rise to problems and undesirable results due, for example, to differential absorption of the ink into a porous substrate, such as a cellulosic web, or spreading or mixing of colours before curing.

In accordance with a first aspect of the present invention, there is provided a process for forming an image upon a moving substrate, the process comprising the steps

of ink jet printing a radiation-curable ink onto the substrate with a print head and subsequently curing the printed image by exposure to appropriate radiation, in which process the time period between printing and curing is substantially the same for all portions of the substrate.

In accordance with a second aspect of the present invention, there is provided, an ink jet printing apparatus for printing onto a substrate with a radiation-curable ink, the apparatus comprising a print head for directing the ink onto the substrate and curing means for curing a printed image by exposure to appropriate radiation, the curing means being adapted to cause the time period between printing and curing to be substantially the same for all portions of the substrate.

The process and apparatus of the present invention are particularly suitable for use in combination with a drop on demand process but, of course, may also be used in combination with other ink jet printing processes, either continuous or intermittent. In the following description, reference will be made only to UV-curable inks but it is to be understood that, where the context permits, reference to other forms of radiation-curable inks is intended.

In accordance with one particular embodiment of the invention, appropriate curing means is arranged in combination with the print head of the ink jet apparatus, travelling therewith so that images printed upon the surface of the substrate are exposed to curing radiation very shortly after having been printed upon the substrate. In such an arrangement it is very difficult, with presently available UV sources, to provide a small enough radiation source connected to and travelling with the print head. In accordance with a particular embodiment of the present invention, a static fixed radiation source is employed and the curing UV radiation is supplied from that source to an irradiation head, of appropriate dimensions, connected with the radiation source by means of flexible radiation conductive means such as a fibre optic bundle or an internally reflective flexible tube.

Alternatively, UV curing radiation may be supplied from a fixed source to the radiation head by an arrangement of mirrors including a mirror upon the radiation head. If desired, unwanted forms of radiation, e.g. visible or infra-red radiation, may be wholly or partially filtered out from the curing UV radiation and this has the advantage

of reducing the amount of unwanted energy supplied to the substrate, thereby avoiding problems such as softening of plastic substrates or embrittlement of cellulosic substrates.

In accordance with another embodiment of the invention the source of UV radiation is arranged not to move with the print head but, rather, takes the form of an elongate radiation source extending transversely across the substrate to be cured and adjacent the transverse path of the print head so that the subsequent rows of images formed by the print head are passed, stepwise or continually, beneath that radiation source.

In a practical arrangement, it may be desirable to provide a plurality of print heads in relative close proximity in a printing station, for printing with different coloured inks to produce a multi-coloured image. Preferably each has its own dedicated radiation source, although provision of a shared source is also possible.

Further advantages may be obtained if the or each curing means is arranged such that the radiation is emitted at a variable distance downstream of the or each respective print head. This adjustment can allow the printed ink droplets to effect a desired degree of spreading/fusion to enhance image quality.

It is also possible to place a second radiation source at a further distance away from the print head or print station. In this way, the two beams of radiation striking the substrate can be arranged to have different intensities, for example the beam(s) striking the substrate nearest to the print head(s) could have a relatively low intensity and the second, further away, beam could have a higher intensity. This has the further advantage that some pre-curing of the printed droplets may be affected by the first beam to provide further control of the amount of spreading/fusion and viscosity of the printed droplets, prior to final curing by the second beam.

UV-curable printing inks are well known and do not form a part of the present invention. For example, our UK patent application no. 9603667.8, unpublished at the priority date of the present invention, discloses a UV-curable ink jet composition comprising an alkoxyated or polyalkoxyated acrylate monomer, a photoinitiator and a colourant. In any event, UV-curable printing inks generally comprise an ethylenically unsaturated monomer or oligomeric binder which polymerises, under the influence of UV-radiation, to form a cured resinous binder. Generally such inks also contain UV

photo initiators serving to initiate polymerisation of the monomer or oligomer on exposure to UV radiation.

The principle underlying the present invention, namely arranging ink jet printing means and curing means so that the time period between printing and curing for any portion of the substrate is substantially the same, may also be applied to other curing systems such as drying or cooling systems.

The present invention will now be explained in more detail by way of the following description of non-limiting embodiments and with reference to the accompanying drawings in which:-

Figure 1 shows an apparatus and process according to a first embodiment of the present invention;

Figure 2 shows an apparatus and process according to a second embodiment of the present invention;

Figure 3 shows an apparatus and process according to a third embodiment of the present invention;

Figure 4 shows a modification of the second embodiment of the present invention, with a variable-position radiation emitting head; and

Figure 5 shows another variant of the second embodiment of the present invention, having two mutually separated radiation-emitting heads.

Turning now to Figure 1, there is shown a substrate 1 moving in the direction of a single-headed arrow 3. A print head 5 arranged for printing with a UV-curable ink traverses the substrate 1 as shown by the double headed arrow 7, in a direction perpendicular to the single-headed arrow 3. A first mirror 9 is fixed to the print head 5. A second mirror 11 is arranged to one side of the substrate, as is a laser 13.

In use, a radiation beam 15 from the laser 13 is reflected via the second mirror 11 and then the first mirror 9 to impinge upon the substrate at a position 17 which is at a fixed distance downstream (i.e. in the direction of travel of the substrate 1 as denoted by the single-headed arrow 3). This fixed position is maintained because the first mirror 9 is attached to the print head 5. The positions of the second mirror 11 and laser 13 are also such that the radiation beam will strike the substrate at this fixed distance downstream of the print head 5.

Turning now to Figure 2, instead of the first mirror 9 shown in the embodiment of Figure 1, a radiation-emitting head 19 is attached to the print head 5. This head 19 is connected via a flexible light-pipe or optical fibre 21 to an external radiation source 23. In use, as the print head 5 traverses the width of the substrate as denoted by the double-headed arrow 7, the radiation emitted by the emission head 19 will always be at a fixed point down stream of the print head in the direction of travel of the substrate.

A third embodiment is shown in Figure 3. In this case, the print head 5 traverses a rail 25 across the width of the substrate as denoted by the double-headed arrow 7. Mounted on this rail, just downstream of the print head 5 is an elongate radiation source 27 which also extends across the width of the substrate 1. Thus, curing of the ink emitted by the print head 5 will always occur at a fixed distance downstream thereof. The elongate radiation source could be, for example, an elongate fluorescent/mercury vapour tube or it could be a continuous light pipe which receives light from an external source by means (not shown) to emit light with substantially uniform intensity along its whole length.

Turning now to Figure 4, there is shown a variant of the second embodiment shown in Figure 2, as seen from one side. Here, the substrate travels in a direction shown by the solid single-headed arrow 29. Attached to the print head 5 is a runner 31 extending downstream of the print head 5. The radiation-emitting head 19 is mounted on this runner so that it can be located in a predetermined chosen position downstream of the head 5, to allow a predetermined air-drying/spreading time for the ink 33 after it is deposited on the substrate.

A further embellishment of the arrangement shown in Figure 4 is shown in Figure 5. Again, the substrate 1 travels in a direction shown by the solid single-headed arrow 29. As well as the print head 5 with downstream-extending runner 31 with radiation-emitting head 19 mounted thereon, there are shown a second print head 35 and a third print head 37 respectively positioned downstream of the first print head 5. These additional print heads show a more usual situation where a plurality of heads is provided to print in respective different colours. Of course, such an arrangement could be used in the situation shown in Figure 4 but are omitted there for clarity.

The additional print heads 35, 37 also have respective downstream-extending runners 39, 41, each of the latter supporting a respective additional radiation-emitting head 43, 45.

Just as the first print head 5 applies respective ink droplets 33 onto the substrate 1, the second and third heads 35, 37 print respective ink droplets 47, 49 at downstream positions on the substrate 1. The positions of the radiation sources 19, 43, 45 are each individually variable along their respective runners 31, 39, 41, relative to their associated respective print head 5, 35, 37.

At a greater distance downstream of the print heads 5, 35, 37 is situated another radiation source 51 extending across the substrate 1. This additional radiation source 51 is adapted to irradiate the image on the substrate 1 with a significantly higher intensity of radiation than the print head specific radiation sources 19, 43, 45.

In use, the embodiment shown in Figure 5 allows low-intensity radiation beam to perform pre-curing of the printed droplets 33, 47, 49 at respective first positions downstream of their print heads 5, 35, 37 to semi-harden/fix the droplets, thus controlling droplet spread and merging. Then a second higher dose of radiation is emitted from the last radiation-emitting head 51 further downstream, to provide complete curing of the printed image.

In the light of this disclosure, modifications of the described embodiment, as well as other embodiments, all within the scope of the present invention as defined by the appended claims will now become apparent to persons skilled in this art.



**CLAIMS:**

1. A process for forming an image upon a moving substrate, the process comprising the steps of ink jet printing a radiation-curable ink onto the substrate with a print head and subsequently curing the printed image by exposure to appropriate radiation, in which process the time period between printing and curing is substantially the same for all portions of the substrate.
2. A process according to claim 1, in which first curing means is provided to direct radiation at the substrate from a first position at a predetermined distance from the print head in the direction of movement of the substrate.
3. A process according to claim 2, wherein the first curing means is adjustable so that the predetermined distance may be varied.
4. A process according to claim 2 or claim 3, wherein second curing means is provided to direct further radiation at the substrate from a second position at a different predetermined distance from the print head in the direction of movement of the substrate.
5. A process according to claim 4, wherein the second curing means provides a higher intensity of radiation to impinge upon the image than that produced by the first curing means.
6. A process according to claim 5, wherein one or more further print heads are provided, each with a respective dedicated curing means at a predetermined distance therefrom, for enabling printing with a plurality of inks of different colours and each of the dedicated curing means provides a lower intensity of radiation than the second curing means.

7. A process according to any of claims 2-6, wherein the first curing means is arranged in combination with the print head for travelling therewith.
8. A process according to claim 7, wherein the first curing means comprises an irradiation head connected to a radiation source by means of flexible radiation conductive means.
9. A process according to claim 7, wherein the first curing means comprises a mirror attached to the print head for directing the radiation onto the substrate, a radiation source being provided in a fixed position so as to transmit radiation to the mirror.
10. A process according to claim 9, wherein the first curing means comprises at least one further mirror for defining an optical path between the radiation source and the mirror attached to the print head.
11. A process according to claim 9 or claim 10, wherein the radiation source comprises a laser.
12. A process according to any of claims 2-6, wherein the first curing means comprises an elongate radiation source extending transversely across the substrate and adjacent the transverse path of the print head so that subsequent rows of images formed by the print head are cured by radiation from the radiation source.
13. A process according to any of claims 7-12 when dependent upon claim 4 or claim 5, wherein the second curing means has the same form as the first curing means.
14. A process according to any preceding claim, wherein the radiation-curable ink is a UV-curable ink.

15. A process for forming an image upon a moving substrate, the process being substantially as hereinbefore described with reference to any of the accompanying drawings.
16. An ink jet printing apparatus for printing onto a substrate with a radiation-curable ink, the apparatus comprising a print head for directing the ink onto the substrate and curing means for curing a printed image by exposure to appropriate radiation, the curing means being adapted to cause the time period between printing and curing to be substantially the same for all portions of the substrate.
17. An apparatus according to claim 16, wherein the curing means comprises first curing means for directing radiation at the substrate from a first position at a predetermined distance from the print head in the direction of movement of the substrate.
18. An apparatus according to claim 17, wherein the first curing means is adjustable so that the predetermined distance may be varied.
19. An apparatus according to claim 17 or claim 18, further comprising second curing means for directing further radiation at the substrate from a second position at a different predetermined distance from the print head in the direction of movement of the substrate.
20. An apparatus according to claim 19, wherein the second curing means is adapted to provide a higher intensity of radiation to impinge upon the image than that produced by the first curing means.
21. An apparatus according to claim 20, further comprising one or more further print heads, each with a respective dedicated curing means at a predetermined distance therefrom for enabling printing with a plurality of inks of different colours wherein

each of the dedicated curing means is adapted to provide a lower intensity of radiation than the second curing means.

22. An apparatus according to any of claims 17-20, wherein the first curing means is arranged in combination with the print head for travelling therewith.

23. An apparatus according to claim 22, wherein the first curing means comprises a radiation head connected to a radiation source by means of flexible radiation conductive means.

24. An apparatus according to claim 22, wherein the first curing means comprises a mirror attached to the print head for directing the radiation onto the substrate, a radiation source being provided in a fixed position so as to transmit radiation to the mirror.

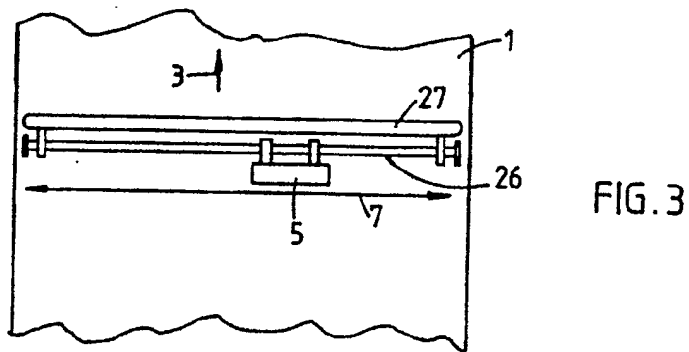
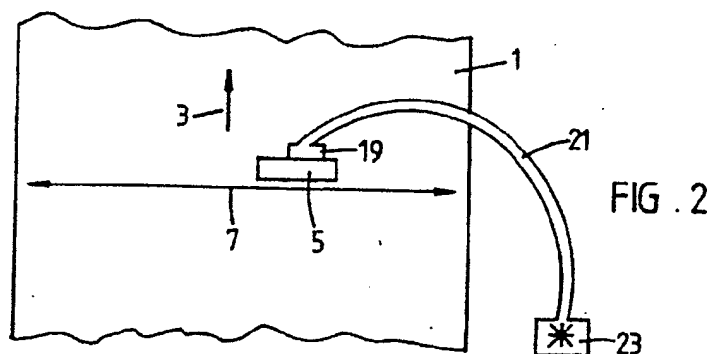
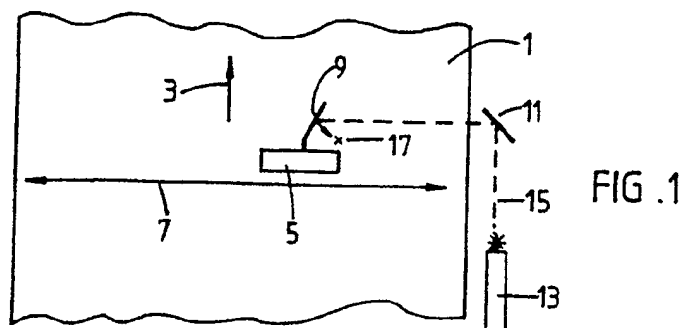
25. An apparatus according to claim 24, wherein the first curing means comprises at least one further mirror for defining an optical path between the radiation source and the mirror attached to the print head.

26. An apparatus according to claim 24 or claim 25 wherein the radiation source comprises a laser.

27. An apparatus according to any of claims 17-21, wherein the first curing means comprises an elongate radiation source extending transversely across the substrate path and adjacent to the transfer path of the print head so that subsequent rows of images formed by the print head are cured by radiation from the radiation source.

28. An apparatus according to any of claims 22-27, when dependent upon claim 19 or claim 20, wherein the second curing means has the same form as the first curing means.

29. An apparatus according to any preceding claim, further comprising a supply of UV-curable ink.
30. An ink jet apparatus for printing onto a substrate with a radiation-curable ink, the apparatus being substantially as hereinbefore described with reference to any of the accompanying drawings.



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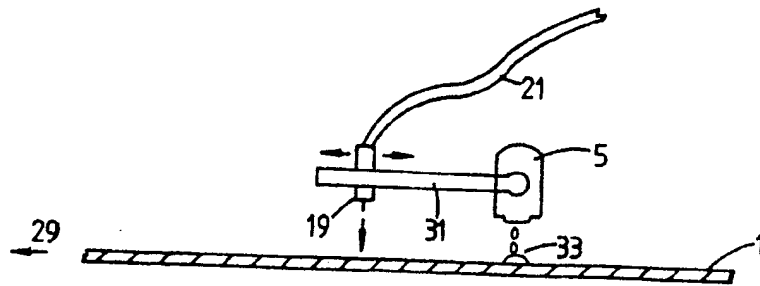


FIG. 4

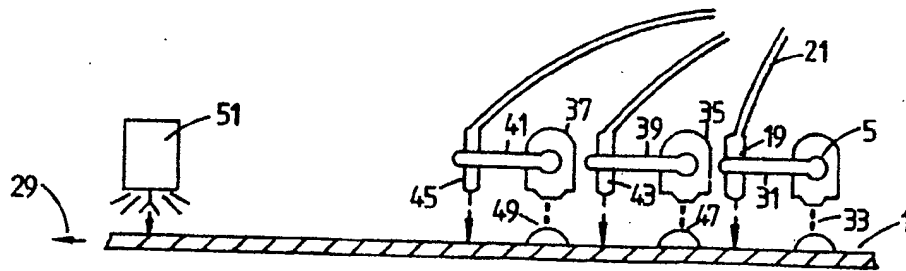


FIG. 5

# INTERNATIONAL SEARCH REPORT

Int. Application No  
PCT/GB 96/01721

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 B41J2/17

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE,A,34 17 376 (CANON) 15 November 1984 see page 4, line 8 - page 6, line 29; figure 1	1,14-16, 29,30
A	---	2,6,17, 21
X	EP,A,0 284 215 (HEWLETT PACKARD) 28 September 1988 see column 3, line 29 - column 6, line 14; figure 2	1,15-17, 30
A	---	2,7,9, 10,12, 16,17, 22,24
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☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

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# INTERNATIONAL SEARCH REPORT

International Application No  
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C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 220 346 (CARREIRA) 15 June 1993 see column 10, line 26 - column 11, line 15; figures 7A-7C ---	1,2, 15-17,30
A	EP,A,0 622 194 (HEWLETT PACKARD) 2 November 1994 see column 7, line 55 - column 8, line 11; figure 7 see column 10, line 18 - column 14, line 20 ---	1,2,7,9, 15-17, 22,24,30
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 505 (M-1194), 20 December 1991 & JP,A,03 222748 (NIPPON PAINT CO LTD), 1 October 1991, see abstract ---	
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Information on patent family members

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